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POWERSTICK DEVELOPMENT

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ABSTRACT

A device called a Powerstick is being developed to satisfy the requirements of several potential solar system exploration missions. The Powerstick is a small power source consisting of three major components: a space qualified heat source (RHU), a thermopile (thermoelectric converter) arrd a set of rechargeable batteries. The PowerStick merges several &vices developed earlier by space power programs. The RHU was developed by DOE for the Galileo and Ulysses missions, the thermopile is a combination of the early RTG technology and pace maker technology with new packaging techniques, and a lithium-ion rechargeable battery is currently being developed for space applications.

NASA has recently awarded a Small Business Technology Transfer (STTR) contract to Hi-Z Technology, Inc. of San Diego to manufacture a miniaturized thermopile and provide a preliminary design of the Powerstick. JPL's Solar System Exploration Program funded Powerstick prototype design and fabrication contract with Swales & Associates, Inc. The Swales unit and the Hi-Z thermopile will be integrated at JPL. This integrated prototype with the thermopile, rechargeable batteries and electrical RHU simulator will be tested at JPL.

At the same time JPL is pursuing a "ruggedized" Powerstick development with the Russian company BIAPOS. BIAPOS is to independently design, build and deliver to JPL for testing their own version of the Powerstick. According to the technology development mad map for small space sources the American and Russian efforts will lead to the development of an engineering and qualification Powerstick unit by the end of the century.

POWERSTICK APPI. ICATIONS

The Powerstick is designed to be used in a small planetary rover, microspacecraft or an autonomous science package that either uses continuous power at a level of a fraction of a watt or can operate intermittently by using energy from the batteries. For example, microseismometers under development at JPL require no more than 1/10 of a watt. Such seismometers require power sources that can last for years due to the sporadic nature of seismic events. An alpha-proton-x-ray spectrometer that is being developed for small rovers to investigate rock composition would require about one third of a watt, which again is within the range of a Powerstick. The next generation of cameras using active pixel sensors operate consuming only a fraction of a watt.

A number of microspacecraft instruments and subsystems could operate using distributed instead of centralized power. Instruments such as magnetometers that must be located on extended booms are perfect candidates for distributed power. Powersticks could also supply spot heating to the devices they power. Such an approach could be considered for a microspacecraft.

The Mars Network missions could take advantage of Powersticks for their mini-meteorological stations. Powersticks could produce enough continuous power to operate a sequencer while trickle charging the batteries. The battery power would be used every couple of weeks to operate the instruments and transmit the data. Without a device like the Powerstick, it will be difficult to operate any instruments in the polar regions of Mars.

A Powerstick could also be carried on a microrover released by a lander. It would increase the mission life from a few days to years. The Powerstick could propel a microrover a few hundred meters in a day, followed by a charging cycle, scientific measurements and data transmission and another charge cycle. This sequence could be repeated for years enabling vast terrain coverage.

POWERSTICK DESCRIPTION

The name Powerstick comes from its appearance reminiscent of a small flash light. The Powerstick is designed to take advantage of complementary operat ion of several modules: the RH U heat source, which supplies heat to the thermoelectric thermopile, which in turn produces electricity used to charge the lithium ion battery. The waste heat from the RHU is used to keep the battery warm. The energy stored in the battery can be used periodically to operate a small lander or a science instrument. A small amount of power is also available continuously from the thermopile. The components of the Powerstick are described below.

The ' ht Weight Radioisotope Heater Unit (LWRHU)

The LWRHU, or RHU, is a standard heat source produced by DoE and designed to provide 1 W of thermal power. The unit is a cylinder 32 mm high, 26 mm in diameter and weighs about 40 g. In the unit, the palletized fuel is surrounded by platinum-alloy capsule, pyrolytic graphite thermal insulation and high technology graphite ablation shell. The unit was designed and built to withstand the worst case re-entry conditions and tested accordingly. A large number of these units are used on the Galileo spacecraft and will be used on the upcoming Cassini mission, this year. The electrical imitators of RHU were designed and built at JPL and will be used for the Powerstick testing.

Thermoelectric Module

Figure 1. Thermoelectric module developed by Hi-Z

The thermoelectric module shown in figure 1, also refered to as the thermoelectric converter TEC, is being developed by Hi-Z Technology, Inc., under an STTR contract with NASA Lewis Research Center. It uses Bi_2Te_3-based materials, both n- and p-type. The materials are vacuum hot-pressed to provide the strength and machining characteristics required to fabricate the long thin legs for the module. The module consists of 18x18 array of legs. Each leg is 0.381 mm on a side and 22.86 mm long (Fig. l). Such a solid array should have superior strength and excellent shock and vibration characteristics. A 0.025 mm thick layer of insulating film is used within the intenor of the module to electrically separate the legs. A layer of 0.064 mm thick insulating film is bonded on the side of the module to prevent electric shorting to the exterior surfaces. Several methods of making the electric contacts required to join adjacent legs of the module are being investigated. The manufacturer is currently sputtering metallic contacts in the pattern necessary to provide a single series electric circuit within the module as well as evaluating several other alternative contacting techniques. When completed, the module is expected to have a peak power output of at least 40 mW in a generator using the 1 W radioisotope heater capsule as a heat source. The matched load voltage will be 5 volts. The weight of the module should be about 7 g.

Container, Support, Insulation

Three versions of the mechanical and thermal design of the powerstick are under investigation including vacuum and gas-filled. The battery is not included in two of the designs but incorporated into preliminary design of the third version.

Vacuum version

Swales Aerospace is responsible for the mechanical and thermal design of one of the versions of the Powerstick. The original Powerstick concept was advanced by engineers at JPL (Chmielewski, Ewell, 1994). The key feature made by Swales to the original JPL concept was in repackaging the device into an evacuated, "can-shaped" design which thermally isolates the RHU from the canister with adjustable titanium tension straps and aluminized Kapton rddiation shields. Other key features of the Powerstick include an aluminum RHU housing (with a vapor-deposited gold exterior), an electrical feed-through. a vacuum port, and an o-ring sealed vacuum housing. The thermal interface between the RHU housing exterior and the thermoelectric module is created by 200 psi pressure produced by the titanium tension straps. Swales is currently under contract with JPL to produce and thermally test a Powerstick prototype. At this writing, the Powerstick prototype is a can-shaped, hermetically-sealed vessel which is 64 mm in diameter, 81 mm long, and about 300 g in mass. Structural analysis results indicate that the Powerstick can easily survive typical launch loads. Thermal analysis results indicate that about 70% of the RHU's 1 W output enters the TEC. The concept is illustrated in fig. 2. Future Powerstick development will involve enhancing its survivability under much higher loads, such as those encountered by postulated Mars probes which may strike and penetrate the Martian surface at moderate-to-high velocities.

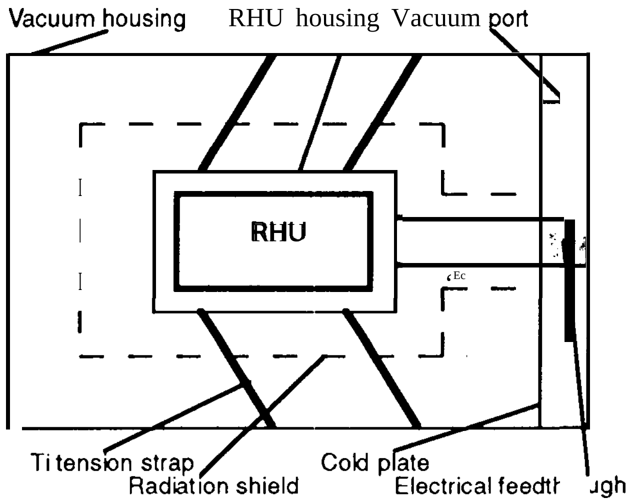

FIG 2 VACUUM POWERSTICK DESIGN

Gas-filled version

This packaging of the powerstick has been proposed by Russian company, BIAPOS. It is bawd on their many years experience in designing and building RTGs. They offered a Xc-tilled titanium canister of 85 mm in diameter and 100 mm high. The heating block will be held by the aluminum separator adjacent to the thermoelectric converter. The mechanical support of the parts inside the housing and thermal interface between separator and thermoelectric converter are provided by adjustable

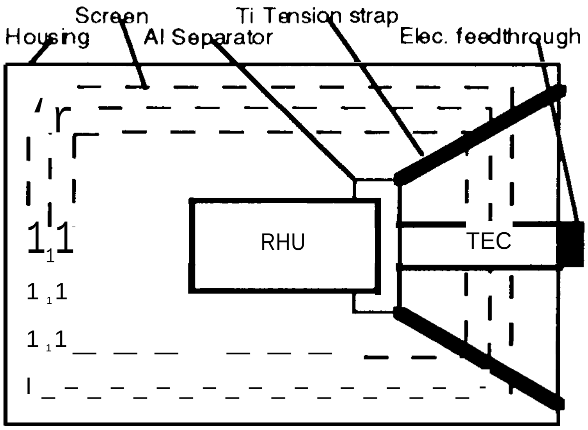

FIG.3 GASFILLED POWERSTICK DESIGN

titanium tension straps. The thermal insulation is provided by multilayer aluminized screen in combination with Xe filling the canister. The thermal conductivity of this gas- screen insulation is 2x 10^{-2} Wt/mK. The BIAPOS design concept is shown in fig.3. The total weight of this assembly when completed is expected to be about 280-300 g.

Hi-Z version

Under the same NASA STTR contract, Hi-Z is also developing a whole powerstick design which will incorporate the TEC described above. The design of the powerstick witt be based on Hi-Z past experience in the development, manufacture and test of small RTG in the late 1970s and early 1980s. The powerstick will incorporate a patented aluminized Kapton multi-foil insulation system which can usc either vacuum or xenon gas back fill. Spring loaded titanium tie wires will be used to hold RHU capsule holder firmly against the TEC both for good thermal contact and to help withstand high shock and vibration loads.

BATTERY

The powerstick described above will be used to trickle charge rechargeable battery(s). The most suitable battery for powerstick was found to be lithium-ion. The battery power will be used intermittently to operate instruments and transmit data. These type of cells arc state-of-the art and have a specific energy of 110 Wh/kg and an energy density of 240 WM which is about three times that of the popular Ni-Cd cells. The prototype of these cells can be purchased from the battery manufacturers. Advanced rechargeable Ii-ion cells are currently under development sponsored by NASA/J PI. Mars Exploration Program. The Powerstick can use two AA-size batteries in series giving an average output of 600 mAb at about 7 volts. Because of the chemistry in the Ii-ion batteries which is sensitive to overcharge and overdischarge, the power-conditioning charge-discharge controller will be built. Each battery of M-type is 18 mm in diameter, 65 mm high and weighs about 40 g. The operating temperature is -20 to +40°C.

CONCLUSION

The development of the Powerstick is important to the NASA space program because it will enable a new class of missions by providing small, low cost, environment independent, very long life power sources. The Powerstick has completed its proof-of-concept phase and is currently in the detailed design phase. The first prototype units will be put on test in summer 1997. It is envisioned that with adequate funding a qualification model can be developed by the turn of the century.

ACKNOWLEDGMENT

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